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Effect of Size, Breed, and Sex Upon Feed Efficiency in Beef Cattle

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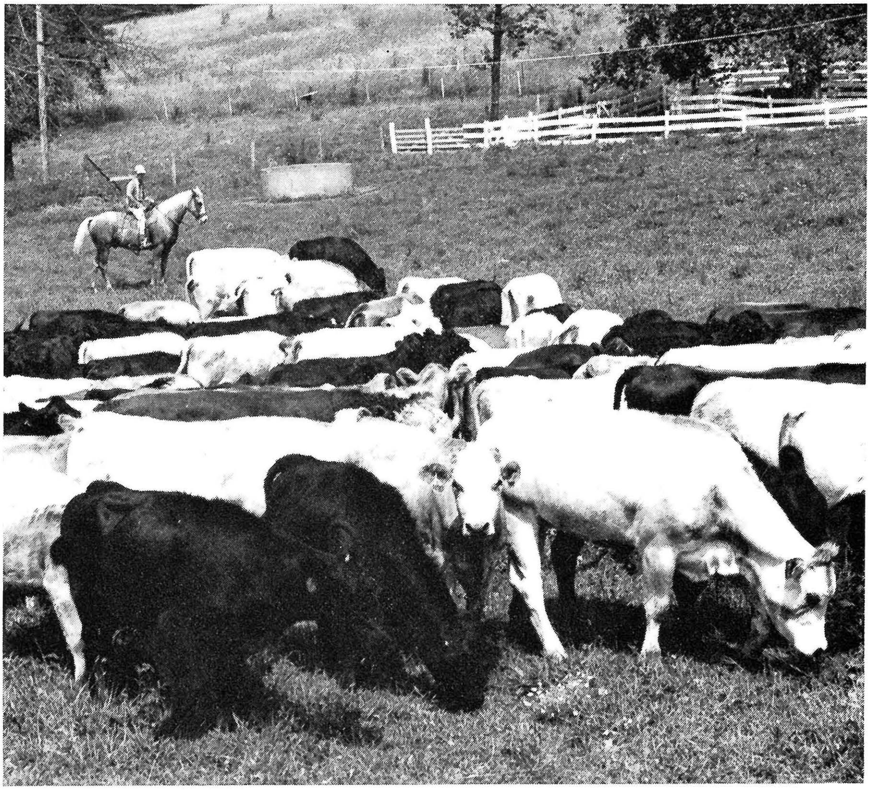

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EFFECT OF SIZE, BREED AND SEX UPON FEED EFFICIENCY IN BEEF CATTLE[1]

EARLE W. KLOSTERMAN and C. F. PARKER[2]

Beef cattle selection and performance testing procedures in recent years have placed much emphasis upon rate of gain. In a search for fast gaining animals, numerous new breeds of larger type have been introduced and selection for gain has increased mature size in a number of herds of existing breeds. Since a large part of the total feed needed for beef production is required to maintain breeding herds and since maintenance requirements are related to size, questions have been raised as to optimum size of breeding animals. Other important items of discussion have been the relationships which exist among size, rate of gain, efficiency of gain, and carcass composition.

The energy requirements of beef cattle and other species have been studied for many years. Numerous articles and books have been written and requirements for all phases of production have been established. No attempt will be made here to review the volume of literature available on the subject. Although much has been accomplished, there are still questions which need to be answered.

Energy requirements of beef cattle have been established by the National Research Council in general terms to meet the needs of the average herd (18). Are these requirements applicable to specific sizes and breeds of cattle or to crossbred individuals? Are there interactions among types of cattle and available feed supplies? The experiments reported here were designed to investigate these questions.

These experiments were designed to compare the relative feed needs of cattle of different size, breed, and sex and not to determine their exact energy requirements. Detailed feed samples, analyses, digestibilities, measurements of energy storage, and losses through direct or indirect calorimetry or comparative slaughter experiments are needed to accurately measure requirements. In some of these experiments, certain analyses and techniques were used to measure energy value. In others, however, only average, published feed analyses were used. Thus, the results presented here are not intended to verify or establish feed requirements. However, the same feeds and measurements were used

[1]A number of these experiments were part of the North Central Regional Project, NC-1, Improvement of Beef Cattle Through Breeding Methods.

[2]Important contributions by the following colleagues to certain phases of this research are gratefully acknowledged: V. R. Cahill, H. W. Ockerman, R. L. Preston, F. M. Byers, C. R. Weaver, F. S. Ruland, R. R. Bishop, L. G. Sanford, J. R. Long, D. R. Beerwinkle, and F. E. Livesay.

for all cattle in any one experiment so that comparisons of different types of cattle within that experiment are valid. Also, if the estimates of feed values used were relatively accurate, the applicable results should approximate requirements.

I. Effect of Breed, Size, and Condition on Beef Cow Maintenance

In a beef breeding herd where less than one calf is marketed per cow per year, the percentage of feed fed which is returned as product in the calf is extremely small compared to that required to maintain the calf and the cow for 12 months. It has been estimated that more than three-fourths of all the feed fed to beef cattle is required for maintenance.

Large individual animals or breeds tend to produce calves which are larger and gain more rapidly at a given age than smaller ones. Within a breed or size of cattle, there is a high positive relationship between rate of gain and economy of gain and also between rate of gain and mature size. With continued emphasis on selection for rate of gain, mature size of the breeding herd can be expected to increase. Will the calves produced by these cattle have a sufficient increase of feed utilization to more than offset the increased feed cost of a larger breeding animal?

PROCEDURE

Two experiments were conducted with mature, non-pregnant, non-lactating Hereford and Charolais cross cows to determine their maintenance requirements. The Charolais cross cows were three-fourths or more Charolais breeding, with the remaining percentages of various beef breeds. The cows were housed in a shed with a small, outside lot and were bedded with sawdust. They were fed individually in

TABLE 1.—Composition of Rations Fed.

	Experiment I		
	Low Protein (%)	High Protein (%)	Experiment II (%)
Ground corn cobs	65	65	65
Dehydrated alfalfa	10	10	10
Ground shelled corn	25	10	15
Soybean meal		15	10
Crude protein	6.9	12.0	9.1

stalls once daily and were managed in groups except during feeding. They were fed one of the rations listed in Table 1 and in addition were allowed free access to trace mineralized salt, bonemeal, and water. The rations were mixed and pelleted.

The cows were weighed weekly and were held away from water overnight prior to each weighing. The initial weight of each cow was used to determine the amount of feed she was to receive and this amount remained constant for the entire test period. The amount of feed fed was determined from its calculated content of total digestible nutrients (TDN) and the equation of Garrett, *et al.* (6), *i.e.* $TDN_m = 0.036\ W^{0.75}$ in pounds. Height of each cow at the hooks was measured in inches and a weight to height ratio was calculated. Statistical analyses were by the method of least squares (8).

Experiment I

Two trials were conducted. Trial 1 was continued for 16 weeks from August 3 to Nov. 23, 1965, and Trial 2 for 15 weeks from Dec. 7, 1965, to March 22, 1966. Cows used in the first trial included 12 Hereford and 2 Charolais. They were cows which had not calved that spring and some carried an extreme amount of finish. The second trial included 11 Charolais and 13 Hereford cows which had all weaned calves that fall and most were thin. The cows were assigned at random within breed and weight group to one of the two rations given in Table 1. Condition of the cows was estimated from an ultrasonic measurement of fat thickness.

Experiment II

This experiment was designed to compare two methods of estimating the maintenance requirements of mature cows and to study the repeatability of these methods. In one method, each cow was fed a constant amount of feed, based on her initial weight, for a 13-week period. This was the same method used in Experiment I. In the other method, each cow was fed at 1.25 times maintenance for 6 weeks. Following an adjustment period of 1 week at 0.75 times maintenance, she was fed at this level for 6 weeks. The average of the gains made on these two levels of feeding was used to test the adequacy of the maintenance ration. Twelve Hereford and 12 Charolais cows were used. These were selected to represent a range in condition from thin to fat.

The repeatabilities of the methods were studied by conducting two 13-week trials. Half of the cows remained on the same method for both trials and the other half were switched to the alternate method for the second trial. Trial 1 was conducted from June 14 to Sept. 13 and Trial 2 from Sept. 20 to Dec. 20, 1966. Condition of the cows was estimated from a visual score.

TABLE 2.—Average Cow Weight, Height, and Feed Consumption.

	Number	Average Weight lb.	Average Daily Ration lb.	Height at Hooks in.	Wt./Ht. Ratio
Experiment I					
Trial 1					
Hereford	12	1104	12.5	47.2	23.4
Charolais	2	1382	14.7	55.9	24.7
Trial 2					
Hereford	13	983	11.7	47.6	20.7
Charolais	11	1063	12.1	52.0	20.4
Experiment II					
Hereford	12	1023	11.9	47.6	21.5
Charolais	12	1148	13.0	53.1	21.6

RESULTS

Weight and height measurements and daily feed consumption of the cows are presented in Table 2 and least square means of average daily weight changes are in Table 3.

Average daily gains of the individual cows were calculated from initial and final weights and these gains were also estimated from regression lines fitted to all weekly weights of each cow. Least squares analyses were conducted on gains obtained by both methods. Standard

TABLE 3.—Least Squares Means, Weight Change per Day, Lb.

	Experiment I	Experiment II
Least squares mean	—0.066	—0.018
Trial 1	0.004	0.141
Trial 2	—0.137	—0.176
Ration		
Low protein	—0.137	
High protein	0.004	
Method		
1.00 x Maintenance		0.015
0.75 x Maintenance		—0.860
1.25 x Maintenance		0.758
0.75 + 1.25/2		—0.051
Breed		
Hereford	—0.007	—0.086
Charolais	—0.126	0.051

errors were 8% and 26% higher in Experiments I and II, respectively, when daily gains were calculated from actual initial and final weights than when these weights were estimated from the individual regression lines. Because of this increased accuracy, the latter method was used.

Results obtained indicate that the energy requirements for maintenance as presently recommended are accurate when used to estimate the amount of feed needed to maintain body weight of mature, non-pregnant, non-lactating beef cows. On the average, cows fed according to these recommendations essentially maintained constant weight for periods up to 16 weeks (Table 3). In some trials, cows made small gains and in others small losses. Also, the average of the weight changes obtained when the 0.75 and 1.25 times maintenance rations were fed approached zero.

Feeding a higher level of protein apparently did not increase the efficiency of energy utilization. Cows fed a 12.0% protein ration and equal amounts of energy did not gain significantly more than those fed a 6.9% protein ration.

When fed in proper proportions to their weight, there was no difference between Hereford and Charolais cows in their maintenance needs. In the first experiment, variation among individual cows appeared to be quite high. However, in the second experiment when the requirements of the same cows were measured twice, there was more difference between the two measurements on the same cow than there was among cows. Thus, it appears there are only small differences among individual cows or breeds of cows in their maintenance energy requirements.

The most consistent and significant observation made in these experiments was a relationship between condition and weight gain. There was a highly significant correlation between fat thickness or score and average daily gain. Cows which had a high degree of finish tended to gain weight, while those in thin condition lost weight. Since the amount of feed fed to each cow was determined from her initial weight, the fatter, heavier cows received more feed per head daily.

DISCUSSION

In these experiments, the cows were fed 0.036 lb. of total digestible nutrients per unit of metabolic weight ($W^{0.75}$). Since this relationship of size and feed requirements is not directly related to body weight, it means, for example, that a 1,500 lb. cow does not require twice as much feed for maintenance as a 750 lb. cow. Figuring on the basis of metabolic weight, if the 750 lb. cow requires 10 lb. of a certain feed to maintain her weight, the 1,500 lb. cow will require 16.7 lb. of the same feed (1.67 times as much as the 750 lb. animal) to maintain her weight.

FIG. 1.—Relationship of daily weight change to condition among mature cows fed at maintenance.

A beef cow may vary widely in weight depending upon her condition, a variation which these experiments suggest may be somewhat greater than the actual variation in maintenance needs of that individual. If, for example, a 1,000 lb. cow is fattened to 1,200 lb. and then fed as a 1,200 lb. cow, she is likely to continue to gain weight. If, however, she is starved to 800 lb. and then fed as an 800 lb. animal, she is likely to continue to lose weight.

In the past when the majority of beef cattle in this country were of the British breeds and were of similar size, weight alone was a reasonable indicator of condition. However, between large and small types of cattle and within certain crossbred herds, weight alone is not an accurate indication of condition. Some measure of condition in addition to body weight is needed to accurately determine the amount of feed needed to maintain a mature beef cow.

A ratio of weight to height was found to be closely correlated with degree of fatness. Cows with a high weight/height ratio gained more than thinner cows with a low weight/height ratio (Fig. 1). Even though Charolais cows were considerably larger and hence higher at the hooks, there was very little difference between them and the Herefords in the weight/height ratio. This relationship of weight to height, therefore, appears useful in describing the condition of cows which may vary widely in type and size.

Statistical analyses of these data, as reported previously (13), were used to develop a formula whereby energy requirements for maintenance can be corrected for differences in weight/height ratio. In practical terms, a thin cow of a given weight will need about 2 lb. more hay daily than an average cow and an average cow 2 lb. more than a fat cow of the same weight just to maintain their respective weights. Since thin cows may need to gain weight during the dry period and fat cows may safely lose weight, the importance of having the cow herd in good condition at the start of the winter feeding season is readily apparent.

In many cattle producing areas it is common for cows to gain weight during the grazing season and lose weight during the wintering period. More information is needed on the net energy efficiency of this practice of alternately gaining and losing fat stores. However, in these experiments, the average amount of feed required at 1.25 and 0.75 times maintenance for equal periods was very similar to the amount required for continuous feeding at the maintenance level. These results suggest that the process of gaining and losing weight is relatively efficient. In any case, even if not highly efficient, it should be more economical for cows to harvest their own feed and store it as fat than to mechanically harvest roughage, store it by some means, and feed it to the cow at a later date.

In these experiments the cows were fed in an open shed with access to an outside lot. Although different trials were conducted during different seasons of the year, there were no significant differences between trials in the amount of feed required for maintenance. This suggests that, under these conditions, the change of seasons in Ohio was not severe enough to change the amount of feed needed for maintenance of cows.

II. Total Feed Efficiency of Beef Production Among Cattle of Different Sizes and Breeds

As indicated in Section I, there were no significant differences between Hereford and Charolais cows in maintenance requirement when this requirement is expressed per unit of metabolic size ($W^{0.75}$). When stated in these terms, larger cattle require more total feed for maintenance. However, this requirement is not in direct proportion to body weight. Larger type cattle would be expected to gain at a faster rate and there is a positive relationship between rate and efficiency of gain.

A beef cow must be fed and maintained for a full year to produce an average of somewhat less than one calf. The series of experiments reported here were designed to compare the total efficiency of beef production among cattle of different sizes and breeds when all feed fed to the cow for 1 year and her calf to slaughter condition are included.

The objectives of these experiments were:

- To determine the total feed nutrients required to produce a unit of edible beef
- To compare various breeds and crosses in their total efficiency of beef production
- To study the effects of size of cattle upon total feed requirements per unit of beef produced.

PROCEDURE

An experiment was conducted during the period 1968 through 1972, with different cows used each year. The plan in each year was to include approximately 10 head each of Charolais, Hereford, crossbred Charolais x Hereford, and crossbred Angus x Hereford cows. Half of each breed group was to be bred to a Hereford bull and half to a Charolais bull. Because of the cattle available, Angus cows and Angus sires replaced the Herefords in the 1971 experiment. However, since the Angus were of similar size to the Herefords, only a limited number of Angus calves were produced and they were confounded within the 1971 experiment. The Angus breed is included with the Hereford breed in this report.

The cows were bred on pasture at the OARDC Outlying Branches in the spring. In the fall when their calves were weaned, they were palpated and if found pregnant were brought to Wooster where individual feeding facilities were available. They were individually fed in stalls once daily the amount of feed calculated from NRC requirements to meet the needs of dry and lactating cows of their specific weight. The energy requirement for each individual cow was adjusted for her initial condition according to her weight/height ratio as outlined by Klosterman, *et al.* (13). When not in their individual feeding stalls, the cows were run in two groups in a barn with access to small outdoor lots. To avoid consumption of bedding, they were bedded with sawdust.

In the first year's study, a complete mixed ration was fed to the cows. However, some health problems were encountered from eating the sawdust bedidng. Therefore, hay, corn silage, and soybean meal were fed to the cows during the remaining years.

When the calves reached 2 months of age, they were tied to individual feeders while their dams were fed, but were allowed to nurse the remainder of the day. They were fed pelleted, 17% protein, alfalfa meal the first year. However, since the alfalfa pellets were not well liked by the calves, the same complete grain mixture fed following weaning was fed in the nursing period during the last 3 years. Milk production of the dams was estimated by the calf consumption method at least twice during the nursing period.

The calves were weaned at about 205 days of age and fed in individual, slotted floor pens until they reached an estimated low-choice slaughter grade. They were slaughtered in The Ohio State University Meat Laboratory, Columbus, where carcass weight, grade, area of rib eye, fat thickness over the rib eye, and percent kidney, heart, and pelvic fat were obtained. By use of appropriate carcass measurements and formulas, the percent of edible portion in the carcass (11) and calories of energy in the empty body (5, 20) were calculated.

When the last of the calves were weaned, the cows were removed from the experiment and a different group of bred cows brought in for the next year's study. Approximately a 30-day period was used to move the cows and to accustom the new ones to the individual feeding facilities. The amount of feed which would have been consumed by each dry cow of her weight during this transition period was extrapolated so that the amount of feed consumed by each cow for a full year was included in the total feed.

Forty cows, palpated to be pregnant, started each experiment. Due to a number of causes (death loss of cows, cows which proved to be open, abortions, loss of calves at birth, and death loss of calves prior to slaughter), final carcass data were obtained on 133 calves. Only these cow-calf pairs which completed the entire experiment were included in the results which were studied by least squares analyses of variance.

RESULTS

Since only a limited number of sires of each breed were used, this variable was not included in the analyses. Two analyses of the data were conducted: 1) to compare three weight classes of cow, and 2) to compare the four breeds. In the first, the cows were arbitrarily divided into three weight classes without regard to breed. Some cows of all

TABLE 4.—Average Results by Weight Class of Cow, Least Squares Means Adjusted for Differences Among Breed, Age of Cow, Sex of Calf, and Years.

	Significance	Overall Mean	Weight Class of Cow		
			1	2	3
Number of cows		133	51	50	32
Av. weight of cow, lb.	**	1035	874	1022	1210
Wt./ht. ratio, lb./in.	**	21.3	18.6	21.2	24.3
Weaning weight, lb.	**	434	405	433	464
24-hr. milk consumption, lb.	*	13.0	12.0	12.7	14.5
TDN to cow, lb.	**	3639	3350	3619	3948
TDN creep, lb.	NS	341	324	351	347
Total TDN, lb.	**	3980	3674	3970	4295
TDN/weaning weight, lb.	NS	9.47	9.36	9.49	9.57
Final weight, lb.	**	930	896	920	973
Gain on feed, lb.	NS	496	491	486	510
TDN on feed, lb.	NS	2560	2495	2535	2650
TDN/gain	NS	5.23	5.13	5.25	5.31
Feedlot gain/mid wt.$^{0.75}$	NS	3.73	3.83	3.69	3.68
Age at slaughter, days	NS	419	416	420	421
Carcass weight, lb.	**	580	561	572	607
Dressing percentage	NS	61.3	61.2	61.3	61.3
Carcass grade†	NS	19.7	19.9	19.6	19.6
Fat thickness, in.	NS	0.54	0.56	0.56	0.53
Percent edible portion	NS	67.1	66.9	66.8	67.7
Weight edible portion, lb.	**	383	368	378	405
Total TDN, cow and calf, lb.	**	6540	6169	6505	6946
TDN/wt. edible portion, lb.	NS	17.2	16.9	17.4	17.3
Empty body energy, Mcal.	NS	1431	1404	1435	1453
Energy EB/ME fed x 100	**	13.4	13.9	13.5	12.8

* and ** Significant at the .05 and .01 levels, respectively.
†Low, average, and high choice = 19, 20, and 21, respectively.

breeds were included in each weight class and the means were adjusted for differences among breeds. In the second analysis, the four breeds were compared, with the least square means adjusted for differences among weight classes. In both analyses, the means were adjusted for differences among years, age of cow, and sex of calf.

The overall averages obtained for the 133 cow-calf pairs and averages for three weight classes of cows, with breed effects removed, are presented in Table 4. The heavier cows had greater weight to height ratios, indicating that they were carrying more condition than the lighter cows.

Milk production of the cow and weaning weight of the calf increased significantly with increased cow weight. However, the amount of TDN consumed by the cow and calf also increased with increased cow weight. This resulted in only small, non-significant differences in amount of TDN required per pound of weaned calf produced. Differences in post-weaning gains and efficiency were not significant among weight classes, but calves from the larger cows were heavier at the end of the finishing phase, produced heavier carcasses and a greater weight of edible beef. There were no significant differences in carcass yield, carcass grade, fat thickness over the rib-eye, or percent of edible portion. As the larger cows and their larger calves consumed significantly more total feed, differences in the amount of TDN required to produce a pound of edible beef were not significant.

On an energy basis, the heavier cows tended to be less efficient as they produced significantly less net energy in the empty body of their calves per unit of total metabolizable energy fed. This difference may have been due to the significant difference in condition of the cows, weight/height ratio, rather than to real differences in size. The cows were fed according to their weight and the fatter cows were heavier. Although an adjustment was made in the amount of feed fed to each cow based upon her initial condition, this adjustment may not have been sufficient for the entire year's feeding period.

Averages by cow breeds, with effects of weight class of cow removed, are presented in Table 5. Although there were significant differences remaining in cow weight, these differences were not large and there were no significant differences among breeds in condition as measured by weight/height ratios.

Hereford x Angus cross cows produced significantly more milk which resulted in heavier calves at weaning and less TDN required per pound of weaning weight, even though there was no significant difference among breeds in amount of TDN fed to the cows or in TDN, in addition to milk, consumed by the calves.

There were no significant differences in final weights, absolute gain, or amount of TDN fed post-weaning among calves from the four cow breeds. However, calves from Hereford x Angus cross cows gained significantly less per unit of weight, relative gain, and required significantly more TDN per pound of gain. This difference was very likely due to the heavier weaning weight and higher condition of calves which resulted from the greater milk production of their dams.

There were no significant differences among calves from the four cow breeds in age at slaughter or in carcass traits except carcass grade. As stated in the procedure, an objective of this experiment was to feed

TABLE 5.—Average Results by Breed of Cow, Least Squares Means Adjusted for Differences Among Weight Class, Age of Cow, Sex of Calf, and Years.

		Breed of Cow			
	Significance	Hereford	Hereford x Angus	Hereford x Charolais	Charolais
Number of cows		34	34	32	33
Av. weight of cow, lb.	*	1028	1008	1041	1064
Wt./ht. ratio, lb./in.	NS	21.6	21.5	21.2	21.0
Weaning weight, lb.	**	413	464	413	447
24-hr. milk consumption, lb.	**	13.3	16.2	10.2	12.6
TDN to cow, lb.	NS	3612	3589	3637	3717
TDN creep, lb.	NS	336	363	331	334
Total TDN, lb.	NS	3948	3952	3968	4051
TDN/weaning weight, lb.	**	10.1	8.6	10.0	9.2
Final weight, lb.	NS	914	930	923	951
Gain on feed, lb.	NS	501	467	510	504
TDN on feed, lb.	NS	2531	2493	2568	2648
TDN/gain	*	5.12	5.40	5.09	5.32
Feedlot gain/mid wt.$^{0.75}$	**	3.87	3.43	3.91	3.72
Age at slaughter, days	NS	419	413	417	427
Carcass weight, lb.	NS	567	578	576	599
Dressing percentage	NS	60.9	61.1	61.4	61.9
Carcass grade†	*	19.7	20.0	19.8	19.2
Fat thickness, in.	NS	0.58	0.61	0.49	0.50
Percent edible portion	NS	67.5	67.1	67.2	66.8
Weight edible portion, lb.	NS	376	382	382	393
Total TDN, cow and calf, lb.	NS	6480	6445	6537	6697
TDN/wt. edible portion, lb.	NS	17.4	17.0	17.3	17.1
Empty body energy, Mcal.	*	1384	1430	1412	1495
Energy EB/ME fed x 100	NS	13.1	13.6	13.2	13.7

* and ** Significant at the .05 and .01 levels, respectively.
†Low, average, and high choice = 19, 20, and 21, respectively.

all calves, regardless of sex, breed, weight, or age, to choice slaughter grade. This was attained with 84% of the 133 head slaughtered, with only 2% grading below high good. The least square means were well within the choice grade and varied less than one-third of a grade. However, there was a tendency for calves out of Charolais cows to be older at slaughter and to grade slightly lower.

Net efficiency (total TDN consumed by the cow and calf divided by pounds of edible portion produced) tended to be similar for all breeds of cow as there were no significant differences among them in this trait. Neither was there a significant difference among breeds on an efficiency of energy storage basis. This is in contrast to the weight class comparison where differences in both weight/height ratios and efficiency of energy use were observed. There were significant differences in energy storage due to the slightly heavier calves from Charolais cows and slightly fatter calves from Hereford x Angus cross cows. However, these differences were not significant when expressed as a percentage of total energy fed.

DISCUSSION

In considering the results of these experiments, it is important to remember that size of cow and breed of cow were compared separately and independent of each other. In studying size, all breeds of cows were included in each weight class and the effects of breed were removed statistically. Likewise, in comparing breeds, the effects of weight class were removed. For this reason, the actual weight differences among cow breeds were greater than the adjusted average weights presented in Table 5.

When comparing breeds of different sizes where it may not be possible to adjust the results statistically, it is necessary to consider breed and size simultaneously. However, with the breeds and sizes used in these experiments, the results would be expected to be the same as those reported here. In neither the size nor breed comparison were there significant differences in the amount of feed required to produce a pound of edible beef. Either larger cattle within a breed or larger breeds would be expected to produce more beef per animal unit. However, these differences would be counterbalanced by the greater feed consumption of the larger cattle. Irrespective of condition as it affects cow weight, calf production by cows of different sizes appears to be in proportion to the size of the cow. Thus, size of cow *per se* seems to be of minor importance in total efficiency of edible beef production.

Two significant breed differences were noted in these experiments. Hereford x Angus cross cows produced significantly more milk which apparently increased the weaning weight of their calves, reduced their efficiency on feed, and produced slightly fatter carcasses. Although fed to a slightly older age, calves from Charolais cows graded significantly lower. This difference among breed types in length of feeding period required to attain a common grade are in agreement with results presented in Section V of this bulletin.

It is of interest that only 13.4% of the metabolizable energy fed to the cow and calf was recovered as net energy in the calf at slaughter. Thus, 86.6% was required for maintenance and other non-productive functions. The data included here are only for cow-calf pairs which completed the experiment and hence are based on a 100% calf crop slaughtered. Actual efficiency of production is somewhat lower than this.

III. Rate of Maturity as a Measure of Efficiency in Beef Cattle Production

The major input for the production of carcass beef is the total feed required by the breeding herd and finishing cattle. As shown in Section II (Table 4), of the total digestible nutrients (TDN) required to produce a slaughter animal to low choice carcass grade, an average of 55% was required by the cow and 45% by the calf. This proportion is based on a 100% calf crop going to slaughter. If the feed required to produce replacement heifers and breeding bulls was included and an average calving percentage was used, the proportion required by the breeding herd would be considerably greater than 55%. Therefore, a high reproductive rate and maximum slaughter weight of offspring for a given cow size are obvious important efficiency traits to improve net efficiency in the production of beef.

Rate of growth has been highly emphasized as an important production trait in beef cattle. However, the relationship between growth rate and efficiency of feed utilization among cattle of various types and sizes fed to similar carcass grade or degree of fatness has not been significant. Kleiber (9) and others, as reviewed by Klosterman (10), have shown that feed efficiency is independent of absolute rate of gain except for animals of the same size. This suggests that cattle with a similar slaughter weight potential but a higher rate of gain would therefore be earlier maturing and more efficient utilizers of feed if terminated on a fat constant basis.

PROCEDURE

The purpose of this section is to report the relationship of rate of maturity with the total feed required by the cow and calf per edible unit of low choice grade beef. The measurement for rate of maturity used in the study was derived by Parker, *et al.* (19) from the following expression:

$$\frac{\text{Weight per Day of Age}}{\text{Slaughter Weight}}$$

which expresses rate of gain as a proportion of final weight and reduces to:

$$\frac{1}{\text{Age at Slaughter}}$$

This function measures rate of growth relative to the body weight at which time the estimated body composition (fatness) would yield a low choice carcass grade. Weight and time on feed do not influence this measure of maturity, nor were they considered for determining the end test point for slaughter of cattle in this experiment.

The data used in this study were obtained from Section II of this bulletin where detailed procedures are outlined. The particular experimental procedure to be recalled here is that all calves were slaughtered when they reached an estimated low choice grade condition regardless of age, weight, or sex and that the effects of sex were removed statistically.

The overall values used to study feed efficiency were the total TDN required by the cow and calf, pounds of TDN needed per unit of edible beef produced, and the total net energy in the empty body per unit of metabolizable energy available from the total feed fed to the cow and calf to slaughter. The overall means for these traits, taken from Table 4, are presented in Table 6.

The least squares method for analysis of variance was used to analyze the experimental data. The statistical model included breed of sire and dam of the calf, sex of calf, year of birth, and a number of covariates, including 1/age at slaughter x 100 to measure rate of maturity.

TABLE 6.—Feed Utilization Traits.*

Trait	Unadjusted Means (lb.)	Standard Deviation
Total TDN (cow and calf), lb.	6439	612
TDN/wt. edible portion, lb.	17.2	1.70
$\frac{\text{Empty body energy, Mcal.}}{\text{Met. energy fed, Mcal.}} \times 100$	13.4	1.54

*Values in this table were from 133 cow-calf records where the average cow weight was 1,035 lb. and the average slaughter weight was 930 lb.

RESULTS

As a covariate, 1/age at slaughter x 100 had a highly statistically significant influence on the three feed utilization traits presented in Table 6. The average age at slaughter was 414.5 days and when expressed as 1/age at slaughter x 100 is equal to 0.2412 with a standard deviation of 0.0172. The correlation calculated from the residual sums of squares and cross products from the least squares analysis between 1/age at slaughter and total TDN was —0.52, indicating that animals with faster rates of maturity were more efficient utilizers of feed. This relationship was highest with TDN required during the post-weaning period ($r = -0.63$), and less ($r = -0.22$) with TDN required by the cow.

There was a slight relationship between consumption during the pre-weaning period with rate of maturity ($r = 0.13$), indicating that faster maturing calves consumed more TDN up to weaning. When 1/age at slaughter was studied as a dependent variable, only the yearly variation and milk production of the dam were statistically significant effects on the total variability of this trait. Higher rates of milk production hastened the rate of calf maturity. However, higher milk production was not directly related to improved feed utilization.

DISCUSSION

The data from this study indicate that, within a given environment, rate of calf maturity (1/age at slaughter) to a low choice carcass condition is an important component of total feed utilization in the production of beef. The importance of this trait in a selective breeding program needs further study to determine the percent of total variation which would respond to selection and its interrelationship with other important traits. The relative importance of rate of maturity among varying sets of environmental conditions also warrants further consideration. For highly intensified beef production systems, a rapid rate of maturity may become a more prominent production characteristic of cattle genetically developed for optimal utilization of the available resources.

IV. Growth of Replacement Heifers of Various Breeds Fed Two Levels of Feed Intake

The net energy requirements of growing and finishing beef steers and heifers of various weights and rates of gain have been estimated (18). These show that, in addition to energy required for maintenance, the net energy required for a specific rate of gain increases with the weight of the animal. These increases are generally believed to be due to changes in body composition as the animal grows and finishes. However, among animals varying in type and size, there can be significant differences in weight without large differences in composition. Thus, a question can be raised as to whether or not currently recommended energy requirements are applicable to crossbred cattle of various types. Specifically, do larger, heavier heifers, with a similar degree of finish, require more energy per unit of gain above maintenance than smaller, lighter weight heifers?

These experiments were designed to compare the growth rate of different sizes of heifers when fed a constant amount of feed in proportion to their weight. Since there were no differences between the Hereford and Charolais breeds in maintenance requirements (Section I), the levels of feeding chosen for these experiments were two multiples of maintenance.

PROCEDURE

The heifers used in these experiments were from herds maintained at OARDC Outlying Branches involved in a breeding experiment designed to compare the combining ability of two different sizes of both beef and dairy breeds. The mating plan used to produce these heifers is given in Table 7.

Heifers from these eight matings were born in the spring, were on pasture with their dams without creep until weaned, and were taken to OARDC in Wooster in the fall. After a short adjustment period to weaning and being tied to individual feeders, they were started on ex-

TABLE 7.—Mating Plan for First-Cross Calves.

	Breed of Sire			
Breed of Dam	Angus (A)	Charolais (C)	Jersey (J)	Brown Swiss (BS)
Angus	A x A	C x A	J x A	BS x A
Charolais	A x C	C x C	J x C	BS x C

TABLE 8.—Performance of Heifers of Different Breeding When Fed at 1.5 or 2.0 Times Maintenance, Least Squares Means (Average of Three Experiments).

	Number of Heifers	Initial Wt. (lb.)	Final Wt. (lb.)	Average Daily Gain (lb.)	Relative Gain* (lb.)	TDN/ Day (lb.)	TDN/ Gain (lb.)	Wt./Ht. (lb./in.)
Level of feeding		NS	**	**	**	**	**	**
1.5 x M	104	390	594	0.97	0.94	5.18	5.47	13.2
2.0 x M	108	387	705	1.51	1.34	7.60	5.12	15.3
Breed Group								
Sire x Dam		**	**	NS	**	**	**	NS
A A	26	353	612	1.23	1.19	5.92	4.96	14.5
A C	17	375	644	1.28	1.19	6.29	5.15	14.2
C A	32	392	655	1.25	1.13	6.43	5.31	14.6
C C	30	420	679	1.23	1.08	6.64	5.55	14.4
J A	29	362	612	1.19	1.14	6.07	5.17	13.8
J C	24	392	641	1.18	1.08	6.43	5.53	13.6
BS A	27	398	677	1.33	1.19	6.53	5.00	14.7
BS C	27	414	677	1.25	1.09	6.81	5.69	14.0
Age of Dam		*	**	**	NS	**	NS	**
3-year-old	34	374	623	1.18	1.12	6.17	5.41	13.7
Mature	178	402	677	1.30	1.16	6.61	5.18	14.7
Year		**	*	NS	NS	**	**	NS
1972-73	77	392	656	1.24	1.12	6.09	5.05	14.2
1973-74	69	372	629	1.22	1.17	6.25	5.22	14.1
1974-75	66	400	664	1.26	1.13	6.83	5.63	14.3

*Relative gain = ADG/Mid Wt.$^{0.75}$ x 100; NS = non-significant difference; * and ** = significant at the .05 and .01 levels, respectively.

periment. A total of 212 heifers born in 1972, 1973, and 1974 were included and identical procedures were followed each year. They were fed 212 days in 1972-73 and 210 days in 1973-74 and 1974-75. Hereford bulls were turned with the heifers during the last 42 days of these feeding periods and remained with them after they were hauled to pasture at the Eastern Ohio Resource Development Center.

Half of the heifers of each breed or cross were fed sufficient feed to supply TDN at 1.5 times their requirement for maintenance and the other half at 2.0 times maintenance. They were tied to individual feeders once daily and were fed a constant amount of corn silage and a sufficient amount of a grain mixture to furnish the specified levels of energy. Urea, limestone, and sulfur were added to the corn silage at ensiling time and the grain mixture was calculated to be adequate in protein so that variable amounts of the two could be fed without significantly changing the protein content of the total ration.

The TDN contents of the feeds were estimated and the amounts fed calculated from the formula of Garrett, *et al.* (6), *i.e.*, $TDN_m = 0.036\ W^{0.75}$ in pounds. The heifers were weighed and the amount of grain mixture adjusted for weight changes every 14 days. Any refused feed was subtracted from the amount offered.

Height at hooks of all heifers was measured at the end of the feeding period and weight/height ratios were calculated.

RESULTS

Results obtained in the 3 years were combined in one analysis of variance with the least square means presented in Table 8. The relative gains presented are a measure of rate of gain per unit of metabolic size and were calculated by the formula, $ADG/Mid.\ Wt.^{0.75} \times 100$.

As would be expected, heifers fed the higher level of feed gained significantly faster and were heavier at the completion of the experiment. Heifers fed the higher level also made greater relative gains and required less TDN per unit of gain, the commonly observed relationship between rate and efficiency of gain.

Comparison of heifers by breed groups shows highly significant differences among them in initial and final weights and, since weight determined the amount of feed fed, in TDN consumed per day. Even though there were highly significant differences in TDN consumption per head daily, there were no significant differences in absolute average daily gains. However, there were highly significant differences in relative gain, gain per unit of weight, and TDN required per unit of gain. Heifers with Angus breeding consistently required less energy per unit of gain than those without Angus sires or dams. Straightbred Angus heifers required 4.96 lb; an average of all half-blood Angus, 5.16 lb; and an average of those without Angus breeding, 5.59 lb. of TDN per pound of gain. There were no significant interactions among breed types and levels of feeding in rate or efficiency of gain.

Heifers from mature dams were heavier at weaning and hence were fed more feed and gained at a faster rate than those from 3-year-old dams. However, there was no significant difference between the two groups in relative gain or efficiency of gain.

There were significant differences in weight of heifers among the three years but, when fed according to weight, no significant differences in absolute or relative gain. Table 8 indicates significant differences among years in TDN required per unit of gain. These differences may well have been due to differences in quality of feeds fed, especially corn silage, rather than real differences in requirements of the heifers. The same estimated TDN content of feeds was used for all 3 years, but differences in silage, at least in dry matter content, were known to exist.

Final weight to height ratios were significantly different between the two levels of feeding and between the two ages of dam. Weight to height ratios of these immature heifers were lower than those of mature cows reported in Section I. However, they are believed to be approximate indicators of condition. Heifers from mature dams were heavier initially, and quite likely fatter, which probably explains their larger, final weight to height ratio.

Some correlation coefficients of interest, calculated on a within subclass basis, are presented in Table 9. Initial weight was positively correlated with absolute daily gain but negatively correlated with relative gain. Absolute gain and relative gain were correlated, 0.79; absolute gain and TDN per unit of gain, —0.73; and relative gain and TDN per unit of gain, —0.91. Thus, even though the two measures of gain were correlated, relative gain was 56% more efficient in estimating feed efficiency than absolute gain was.

TABLE 9.—Within Subclass Correlations Between Certain Traits.

	Initial Wt.	Average Daily Gain	Relative Gain	TDN per Day	TDN/ Gain	Wt./Ht.
Initial weight	1.00	0.31	—0.30	0.87	0.27	0.83
Av. daily gain		1 00	0.79	0.57	—0.73	0.71
Relative gain			1.00	0.00	—0.91	0.20
TDN per day				1.00	0.07	0.87
TDN/gain					1.00	—0.18
Wt./Ht.						1.00

DISCUSSION

In considering the results obtained in this experiment, it should be remembered that feed intake was controlled and calculated from initial weight and each subsequent 14-day weight, with weights taken to the three-fourths power (metabolic size). The two levels of feeding were also based on two multiples of maintenance which are stated in terms of metabolic size. That is, any difference in appetite which might exist among breed types was not permitted to operate, nor could compensatory gain occur if influenced by appetite.

Under the conditions of this experiment, the results show that NRC recommendations of the net energy requirements for gain of heifers varying in weight are applicable to heifers varying in size. Even though the heavier, larger type heifers were fed more feed per head daily, their absolute gains were not significantly greater than the smaller type heifers. It was not possible to accurately measure differences in body composition which might have existed among the heifer types used in these studies. However, larger-type heifers would not be expected to be, nor did they appear to be, fatter at weaning than the smaller type heifers. Thus, different energy requirements for gain of calves of different types do not appear justified.

On a within subclass basis, final weight/height ratio was highly correlated with initial weight, 0.83, and average daily gain, 0.71. It was also correlated with relative gain, 0.20; TDN fed per day, 0.87; and TDN per unit of gain, —0.18. These correlations suggest that initial and subsequent 14-day weights, which determined TDN fed daily, may have been influenced by body composition. The significant difference in weight/height ratio due to age of dam also indicates that initial weight and TDN fed were influenced by initial body composition.

As indicated in Section I, the maintenance requirement of fat cows per unit of metabolic size was lower than that for thin cows and an accurate estimate of maintenance should consider differences in condition. Although not significantly different, the weight/height ratio of straightbred Angus heifers was 14.5, an average of all half-blood Angus was 14.3, and an average of those without Angus breeding was 14.0. Thus, it seems possible that the differences in relative gain and feed efficiency observed among breed groups may have been due to an inaccurate estimate of maintenance among breed types if initial and subsequent weights and TDN fed were influenced by differences in body composition.

The results of these experiments illustrate the importance of using relative gain rather than absolute gain as an indicator of efficiency when comparing cattle of different types. While no significant differences among breed types were found for absolute rate of gain, highly significant differences existed for relative gain and for the amount of feed required per unit of gain.

V. Performance and Carcass Traits of Large and Small Type Growing-Finishing Steers

Rate of gain, efficiency of gain, and ability to finish at a desired weight are important traits in feedlot cattle. The results obtained from growing-finishing experiments with different types of cattle may differ if they are fed for a constant time, to a constant weight, or to a constant grade.

Two experiments were conducted to compare steers of different breed types when finished following weaning. Although all breed types were not included, these steers were from the same breeding experiment as the heifers reported in Section IV.

EXPERIMENT I

Procedure

Twenty-eight steers of diverse breed and size were individually fed in slotted floor pens. They were started on experiment at approximately 8 months of age and fed a ration of 5 lb. of corn silage, 2 lb. of a protein supplement, and cracked corn full-fed. They were slaughtered in The Ohio State University Meat Laboratory when each steer appeared to have reached approximately 30% carcass fat and low choice grade.

TABLE 10.—Breed Means for Performance and Carcass Traits Adjusted to Equal Carcass Fat Content.

	Brown Swiss x Charolais	Jersey x Angus	Charolais	Angus	Charolais x Angus
Number of steers	5	6	5	6	6
Beginning wt. (lb.)	469	416	478	440	485
Slaughter wt. (lb.)	1007	845	1058	862	968
Days on feed	248	190	251	162	212
Av. daily gain	2.18	2.29	2.42	2.53	2.33
Av. daily feed (lb.)	10.90	10.17	10.65	10.68	10.81
Daily feed/$W^{0.75}$ x 100 (lb.)	7.67	8.07	7.29	8.27	7.72
TDN/gain	5.00	4.44	4.40	4.22	4.64
Marbling*	23.7	23.1	22.6	20.9	20.6
Carcass grade†	19.3	19.4	19.2	18.6	18.5

*Marbling: 20 = small⁻, 21 = small°, 22 = small+, 23 = modest⁻, etc.
†Carcass grade: 18 = good+, 19 = choice⁻, 20 = choice°, etc.

Results

Averages of live performance and carcass traits of the different breed combinations fed were statistically adjusted to equal percent carcass fat and are presented in Table 10. There were large differences in days fed and slaughter weight. The Brown Swiss x Charolais and Charolais steers were heavier when slaughtered and required a longer time on feed than the Angus or Jersey x Angus steers. The Charolais x Angus were intermediate in both slaughter weight and days fed. When fed to comparable finish, differences among breeds for average daily gain, TDN required per pound of gain, marbling, and carcass grade were small, statistically non-significant, and did not show any trends related to final slaughter weight.

There were significant differences in daily feed intake per unit of metabolic size and these were negatively, closely related to the number of days required to reach low choice grade.

EXPERIMENT II

Procedure

Sixteen head each of Angus and Charolais steer calves were fed in this experiment. All calves were implanted with Synovex-S at the start of the experiment and again after they had been on feed for 84 days. Half of the calves within each breed group were full-fed limestone-treated corn silage and 2 lb. per head daily of a complete protein supplement. The remaining calves were full-fed dry, whole shelled corn, 5 lb. of limestone-treated corn silage, and 2 lb. of the same protein supplement. The steers were fed in two groups according to the rations fed so feed consumption and requirements by breed were not obtained.

Upon reaching slaughter condition, the steers were shipped to the Meat Laboratory for carcass evaluation. Additionally, specific gravity was measured on the left side of each carcass to determine the carcass fat content of each steer.

Results

The feedlot performance of these steers is shown in Table 11. As expected, gains and feed efficiency were greater on the high-concentrate ration than on corn silage. Charolais steers gained at a faster rate than Angus steers. Steers on the silage ration were fed somewhat longer than those on the concentrate ration. Unfortunately, it was not possible to feed the silage ration until the steers were equal in weight to those fed the concentrate ration.

Carcass characteristics of these steers are shown in Table 12. In order to compare carcass traits of the two rations at equal carcass weights, all carcass data were adjusted statistically to the average hot

TABLE 11.—Corn Silage vs. High-Concentrate Rations for Steers—Feedlot Results.

	Silage		Concentrate	
	Angus	Charolais	Angus	Charolais
Number of steers	8	8	8	8
Initial weight, lb.	430	479	417	482
Final weight, lb.	844	968	938	1093
Days on feed	200		186	
Av. daily gain, lb.	2.07	2.45	2.82	3.27
Av. daily ration:				
Corn silage, lb.	32.6		5.5	
Whole corn, lb.			14.2	
Supplement, lb.	2.0		2.0	
DM/gain	6.59		5.37	

carcass weight of each breed, *i.e.*, 569 lb. for the Angus steers and 658 lb. for the Charolais steers. This adjustment allows the data to be evaluated as though the steers had been fed to the same final weight. Using the average daily gains shown in Table 11, it can be calculated that to reach equal final weight, steers fed the silage ration would have required 223 days and the concentrate fed steers 165 days to reach the carcass weights shown in Table 12.

Steers full-fed corn silage would be expected to have more fill at slaughter than those fed corn grain, and hence a lower carcass yield.

TABLE 12.—Corn Silage vs. High-Concentrate Rations for Steers—Carcass Traits.*

	Silage		Concentrate	
	Angus	Charolais	Angus	Charolais
Number of steers	8	8	8	8
Hot carcass wt., lb.	569	658	569	658
Dressing percentage	63.7	64.2	65.0	63.9
Marbling score†	5.0	3.4	5.7	4.0
Grade‡	19	15	19	17
Fat thickness, in.	0.60	0.25	0.68	0.24
K-P-H fat, %	3.0	2.4	3.0	3.0
Area rib eye, sq. in.	10.0	11.8	10.5	12.8
Yield grade	3.6	2.3	3.6	2.1
Carcass fat, %	28.0	19.3	31.8	22.2

*All data adjusted to the mean hot carcass weight within breed.
†3 = trace, 4 = slight, 5 = small, 6 = modest.
‡Low, average and high choice = 19, 20, 21; good = 16, 17, 18; and standard = 13, 14, and 15, respectively.

This was apparent in the Angus breed but not the Charolais. When fed to equal weights, there was no difference in carcass grade between Angus steers fed silage or grain. However, Charolais steers fed silage graded two-thirds of a grade lower than those fed grain. Total carcass fat, as determined by specific gravity, was higher for both breeds when fed the concentrate ration.

When fed for the same length of time on either the silage ration, 223 days, or the concentrate ration, 165 days, Angus steers were generally fatter than Charolais steers. This was expressed in total carcass fat, marbling score, fat thickness, final grade, and yield grade. However, when fed the concentrate ration, there was no difference between the breeds in kidney-pelvic-heart fat. As would be expected with leaner carcasses, Charolais steers had larger rib-eyes and higher yield grades.

DISCUSSION

The two experiments reported in this section illustrate the differences in results which may be obtained when cattle of different size and breed are fed to a constant carcass composition, for a constant length of time, or to constant weights on different rations. When fed to a constant composition in Experiment I, there were large differences in slaughter weight and days fed, but only small non-significant differences in average daily gain, feed efficiency, marbling score, and carcass grade. Although a limited number of steers were used in this study, results are in agreement with those of Hankes, *et al.* (7) and others.

When fed for a constant period of time on either a corn silage or high concentrate ration in Experiment II, there were large differences between Angus and Charolais steers in both rate of gain and carcass composition. When fed to the same within breed weight on the two rations, there appeared to be a breed x ration interaction in carcass grade. Angus steers of the same weight graded low choice on either the silage or concentrate ration. However, Charolais steers of equal weights graded two-thirds of a grade lower on the silage ration. To grade the same, Charolais steers would need to be fed the high-concentrate ration longer than Angus steers and Charolais steers fed the silage ration would need to be fed longer and to heavier weights than Charolais steers fed the concentrate ration. This breed x ration interaction has been verified by recent, unpublished data obtained in this department (4).

VI. Effect of Sex Upon Net Energy Value of Corn Silage and Ground Ear Corn When Fed Separately or in Combination to Steers and Heifers

Net energy is the most accurate measure of the energy value of a feed for productive purposes. Net energy is determined by subtracting the energy lost through the feces, urine, combustible gases, and heat increment from the total gross energy of a feed. Thus, by definition, net energy is the amount of energy in a feed which is available for the production of growth, fattening, milk, etc.

Net energy values may be determined with a respiration calorimeter or a respiration chamber where all heat losses are measured directly or estimated indirectly from gaseous exchange. These methods have a number of definite limitations. They are costly in equipment and labor. Only a limited number of animals can be used and these can be used only for a short time and under unnatural conditions.

A method of estimating net energy values of feeds for beef cattle with a comparative slaughter technique has been developed by Lofgreen (17). This method is based upon the amount of energy stored by a group of animals fed a specified ration for a period of time. A representative sample of animals is slaughtered at the beginning of the experiment and their chemical composition is determined by the specific gravity of the carcass. At the end of the experiment, the same information is obtained on cattle fed the ration being tested. From the composition of the carcass at the start and the end of the experiment, the amount of energy stored from a measured amount of feed can be determined.

This method, with minor modifications, was used in these experiments to estimate the net energy value of corn silage, ground ear corn, and a combination of the two when fed to growing-finishing steers and heifers.

Steers and heifers can both be fattened satisfactorily on a variety of rations. There are some basic differences, however. Most notable of those is the more rapid fattening of the heifer. When fed the same ration, heifers will fatten at an earlier age and lighter weight than steers. The objective of these experiments was to determine if the net energy value of rations varying in energy content might differ when fed to steers or heifers.

PROCEDURE

Two experiments were conducted at the OARDC Northwestern Branch. Two concrete stave silos were filled with well-eared, well-matured, whole plant corn to which 10 lb. of urea, 10 lb. of ground limestone, and 2 lb. of dicalcium phosphate were added per ton at the time of ensiling. Whole ear corn was ground through a burr mill prior to feeding. Other feeds included were: a mixture of ground ear corn, 85%, and urea, 15%; pelleted dehydrated alfalfa (17% protein, 100,000 units vitamin A); trace mineralized salt; and a mixture of 4 parts steamed bonemeal and 1 part salt. Dry matter of the silage and ear corn was determined each 14-day period.

Choice quality Hereford steers and heifers were purchased from a single ranch in northern Texas and shipped to Ohio in early October. The supply of silage available was not adequate to feed the cattle from this date until the desired final weight. So all cattle were fed the same ration of hay and grain until the experiments were started in late December. At the start of the experiments, the steers were implanted in the ear with 30 mg. of stilbestrol and the heifers with 15 mg.

Initial and final live weights were shrunk weights taken after the cattle were held off feed and water overnight. Steers and heifers were randomized within weight groups in three lots each. Three steers and three heifers were selected at random within weight groups and slaughtered to determine initial body composition.

The objective was to feed the heifers to an average weight of 850 lb. and the steers to 1,000 lb. This was nearly attained in all instances except for steers full-fed silage in the first experiment because the supply of silage was inadequate to carry them to that weight.

When a lot of cattle reached the desired weight, a shrunk weight was taken and the animals were paired according to weight. One animal of each pair was randomly selected for slaughter in The Ohio State University Meat Laboratory and the other was sold at local auction.

The empty body weight of the cattle slaughtered was calculated by subtracting the weight of paunch fill from the live weight at slaughter. This empty weight was expressed as a percentage of the shrunk weight taken prior to shipment. This percentage was then used to estimate the empty weight of the animals fed in the experiment.

Detailed carcass data were obtained which included separating the round, loin end, rib, and chuck into edible portion, bone, and fat trim. These results were used to estimate the percentages of each in the total carcass. The 9-11 rib section minus the bone was ground and sampled for the determination of moisture, fat, protein, and ash. The percent body water of the empty body weight was estimated by the following formula, which was derived from equations presented by Kraybill, *et al.* (16):

Percent Body Water = 72.3 — (0.6227) (Percent Fat 9-11 Rib)

This percentage was used to estimate total energy content of the empty body according to the procedure outlined by Lofgreen (17). Differences in energy content of the initial and final samples of cattle were used to determine energy storage and the net energy value of the rations fed. The constant used to estimate the amount of energy expended for maintenance was $75W^{0.75}_{kg}$.

TABLE 13.—Performance of Steers and Heifers Full-Fed Corn Silage, Ground Corn, or a Combination of the Two (Experiment I).

	Silage		Silage + Corn		Corn	
	Steers	Heifers	Steers	Heifers	Steers	Heifers
Number	14	14	14	14	13	14
Av. initial wt., lb.	575	554	570	557	575	560
Av. final wt., lb.	943	841	993	851	998	836
Av. daily gain	1.94	1.87	2.52	2.22	2.25	2.19
Days fed	189	154	168	133	189	126
Av. daily ration, lb.						
Corn silage	35.6	34.3	10.0	10.0		
Ground ear corn			13.5	11.7	14.9	14.3
Corn-urea mix			1.2	1.2	1.5	1.5
Dehydrated alfalfa	1.0	1.0	1.0	1.0	1.0	1.0
Total dry matter	14.5	14.0	16.9	15.4	14.4	14.0
Dry matter per cwt.	1.90	2.01	2.16	2.19	1.83	2.01
Feed per cwt. gain, lb.						
Corn silage	1832	1841	396	449		
Ground ear corn			536	526	663	653
Corn-urea mix			48	54	67	68
Dehydrated alfalfa	51	54	40	45	45	46
Total dry matter	748	754	670	692	643	637
Dressing percentage	59.2	59.3	61.4	60.8	62.1	60.3
Marbling score*	4.7	5.7	5.7	5.6	5.6	5.7
Final grade†	17.7	19.3	19.3	18.9	19.2	18.9
Fat thickness, inches	0.28	0.50	0.42	0.57	0.50	0.37
Area rib eye, sq. in.	10.0	8.9	10.0	9.5	9.6	9.1
Edible portion, %	72.6	67.8	70.1	67.0	71.1	60.0
Bone, %	18.1	16.1	15.8	14.5	15.7	15.3
Fat trim, %	9.3	16.1	14.1	18.5	13.2	15.7
Tenderness score	22.4	22.5	16.0	25.1	18.9	19.5

*Slight = 4, small = 5, and modest = 6.

†Low, average, and high good = 16, 17, and 18; low, average, and high choice = 19, 20, and 21, respectively.

RESULTS

Feedlot results and carcass data obtained in Experiment I are presented in Table 13 and Experiment II in Table 14. Total percentages of edible portion, bone, and fat trim and tenderness scores were obtained in the first experiment but not in the second.

Results obtained in the two experiments are in good agreement and also with previous comparisons of steers and heifers. Steers ate slightly more feed per head daily and gained faster than heifers. However, on a per unit of weight basis, the heifers consumed more dry matter daily and were fatter at a final weight of about 850 lb. than steers were at 1,000 lb. Even though the heifers were fatter when fed to these weights, there was very little difference between the sexes in amount of dry matter required to produce 100 lb. of live weight gain.

TABLE 14.—Performance of Steers and Heifers Full-Fed Corn Silage, Ground Ear Corn, or a Combination of the Two (Experiment II).

	Silage		Silage + Corn		Corn	
	Steers	Heifers	Steers	Heifers	Steers	Heifers
Number	14	14	14	14	14	14
Av. initial wt., lb.	599	572	600	572	600	572
Av. final wt., lb.	978	847	983	843	990	821
Av. daily gain	1.93	1.87	2.38	2.27	2.08	1.87
Days fed	196	147	161	119	188	133
Av. daily ration, lb.						
Corn silage	44.0	42.4	10.0	10.0		
Ground ear corn			13.2	12.6	15.1	14.0
Corn-urea mix			1.2	1.2	1.5	1.5
Dehydrated alfalfa	1.0	1.0	1.0	1.0	1.0	1.0
Total dry matter	13.8	13.3	15.4	14.9	14.2	13.4
Dry matter per cwt.	1.75	1.87	1.95	2.11	1.79	1.92
Feed per cwt. gain, lb.						
Corn silage	2278	2264	419	438		
Ground ear corn			555	554	724	751
Corn-urea mix			50	53	72	80
Dehydrated alfalfa	52	53	42	44	48	53
Total dry matter	713	711	648	657	685	718
Dressing percentage	61.4	60.8	61.7	61.0	60.7	60.3
Marbling score*	5.1	6.5	5.4	5.4	5.2	4.5
Final grade†	19.7	19.1	20.4	18.8	19.8	19.5
Fat thickness, inches	0.42	0.56	0.43	0.46	0.38	0.42
Area rib eye, sq. in.	9.5	8.8	9.7	9.6	9.5	9.6

*Slight = 4, small = 5, and modest = 6.

†Low, average, and high good = 16, 17, and 18; low, average, and high choice = 19, 20, and 21, respectively.

TABLE 15.—Composition of Gains of Steers and Heifers Fed Corn Silage, Ground Ear Corn, or a Combination of the Two (Average of Two Experiments).

	Silage		Silage + Corn		Corn	
	Steers	Heifers	Steers	Heifers	Steers	Heifers
Av. empty wt. gain, lb.	322	244	376	256	362	240
Fat gain, lb.	119	158	178	154	172	116
Protein gain, lb.	51	21	52	24	50	31
Composition of gain:						
Fat, %	37.0	64.7	47.6	60.2	47.0	48.4
Protein, %	15.8	8.5	13.8	9.6	13.7	13.0
Water and ash, %	47.2	26.8	38.7	30.2	39.2	38.5
Energy gain, Mcal/day	3.313	4.834	5.436	5.700	4.548	4.472
Protein gain, lb./day	0.27	0.14	0.32	0.20	0.26	0.24

Average daily gains and feed intake were greatest when a combination of corn silage and ground ear corn was fed. Feed requirements per unit of gain tended to be higher on the all-silage ration. However, the amount of beef produced per acre of cropland is generally greater with increased proportions of corn silage in the ration. An accurate comparison of the merits of corn silage, ear corn, and shelled corn

TABLE 16.—Net Energy Value of Corn Silage and Ground Ear Corn Rations When Fed to Fattening Steers and Heifers (Average of Two Experiments).

	Silage		Silage + Corn		Corn	
	Steers	Heifers	Steers	Heifers	Steers	Heifers
Av. of initial and final empty wts., lb.	690	628	716	634	710	628
Av. metabolic wt., $W^{0.75}_{kg}$	74.6	69.4	76.6	70.0	76.2	69.4
Energy required for maintenance, Mcal/day (M)*	5.595	5.205	5.745	5.250	5.715	5.205
Energy gain, Mcal/day (P)	3.313	4.834	5.436	5.700	4.548	4.472
Total net energy, Mcal/day (M+P)	8.908	10.039	11.181	10.950	10.263	9.677
Dry matter intake, lb./day	14.2	13.7	16.2	15.2	14.3	13.7
Net energy, Mcal/100 lb. DM	62.7	73.3	69.0	72.0	71.8	70.6
Net energy of ration as fed, Mcal/100 lb.	22.0	25.6	43.6	44.9	58.6	57.9
Net energy value for heifers as percent of steer value		116		103		99

*Energy requirement for maintenance estimated to be $75W^{0.75}_{kg}$.

should include costs of harvesting, storing, and feeding. These costs may vary with the size of the total cattle feeding enterprise and the availability of labor.

Chemical composition of the gains (Table 15) shows that increases in empty body weight of heifers were considerably higher in fat and lower in protein than those made by steers. This resulted in a greater storage of calories by heifers and, on the average, a higher net energy value of rations when fed to heifers (Table 16). There was an interaction among rations and sexes in this regard. The net energy value of the corn silage ration averaged 16% higher when fed to heifers than when fed to steers. This difference was consistent in both experiments, being 15% in the first experiment and 17% in the second. There was little difference in net energy value of the ear corn ration when fed to either steers or heifers.

The increased intake of ration dry matter per 100 lb. of live weight by heifers over steers was consistent with all three rations in both years. This greater intake over and above maintenance needs would leave more energy for body storage in heifers than in steers. Although the primary purpose of finishing cattle is to fatten them, the higher fat content of the heifer carcass is not considered desirable. As shown in Table 15, steers stored more protein per head daily than heifers.

DISCUSSION

Heifers are generally considered to be less efficient in the conversion of feed to beef than are steers. However, in most comparisons they have been fed to a higher degree of finish. In the present experiment, when the heifers were fed a considerably shorter period of time and to final weights 150 lb. lighter than steers, there was very little difference in the amount of dry matter required per unit of gain. Even so, carcass data show the heifers to have been fatter than the steers. In view of their greater feed intake per unit of weight and higher energy content of carcass, heifers appear to be more efficient converters of energy than steers. This is of no apparent advantage if heifers must be fed to a higher body fat content to have the same quality grade as steers, which appeared to be the case in these experiments.

In view of the differences between steers and heifers in feed intake per unit of weight and in ease of fattening, more emphasis should be given to differences in rations which might be fed to each. The interaction between sex and ration value observed in these studies indicates that heifers are especially well adapted to the use of a corn silage ration.

VII. General Discussion

The primary objective of these experiments was to determine if differences exist among sizes, breeds, and sexes of cattle in their energy requirements for maintenance, growth, and finishing. Secondly, are there interactions among types or sexes and available feed supplies? Reproduction was not considered in these studies and milk production was involved in only one experiment in which total requirements were measured.

It is not clear from results reported here whether there are differences among cattle types in maintenance requirements. There appeared to be no real difference between mature Hereford and Charolais cows per unit of metabolic weight. However, data from growing weanling heifers suggested a difference between Angus and other breeds. In the mature cow experiment, there were significant differences between fat and thin cows. In the heifer experiment, differences in condition were not as great and unfortunately could not be accurately measured.

Ayala (3) reported an apparent difference between Angus and Holstein cattle in maintenance requirements. However, as reviewed and discussed by him, maintenance requirements decrease with age, and the Angus cattle were approximately 3 months older and considerably fatter than the Holsteins. Either actual age or physiological age are related to stage of maturity and ease of fattening. As will be discussed later, this trait and a number of other differences between sexes appear analogous to differences among breeds which vary in size. Klosterman, *et al.* (15) found no difference in maintenance requirements between growing Hereford bulls and heifers. Therefore, it is the opinion of the authors that differences in maintenance requirements which may exist among sizes, breeds, and sexes of cattle are relatively small and these may be related to physiological age or body composition. When feed requirements for growth and finishing of different types of cattle are compared, it is important that they be fed to the same final body composition. Likewise, when maintenance requirements are estimated from body weight, it seems important that this be done with some consideration of body composition.

Rate of gain, over and above maintenance, is clearly an important trait in beef cattle. However, in order to have a meaningful relationship to maintenance, and hence to total feed efficiency, gain must be related to weight or metabolic size. This relationship of gain to body weight is expressed as relative gain in this bulletin.

For economic reasons as well as for the quality of product produced, it is important that cattle be finished for slaughter at young ages. To accomplish this, it is necessary that all types be fed relatively expensive finishing rations for some period of time. Thus, ability to finish is also an important trait in beef cattle.

When finished for slaughter prior to maturity, gains are a combination of bone, lean, and fat deposition. However, relative rates of deposition change with maturity. As rate of fattening increases with age, rate of maturing or relative physiological age play an important role in beef cattle efficiency. Since live weight gain includes both lean and fat, those animals which deposit the maximum combination of the two per unit of weight will have the greatest relative gain and be the most efficient.

Results reported in this bulletin (and elsewhere) show that when cattle of different sexes or sizes are fed to similar weights or, for similar periods of time, there will be marked differences among them in rate of gain, efficiency of gain, and body composition. When fed to similar body composition, differences in rate of gain decrease and differences in efficiency become relatively small. However, differences in slaughter weight and length of feeding period required to attain that composition become large.

Supplies of finished slaughter cattle vary with supplies of feed grains and cattle numbers. However, a desired degree of finish is generally preferred, with both underfinished and overfinished cattle selling at a discount. Much discussion has been given to a most preferred slaughter weight. In the market, however, size independent of finish has been of much less importance than the desired degree of finish. Under these conditions it seems most logical to compare cattle of different types when they are fed to a desired market condition.

Rate of relative gain, feed efficiency, and rate of maturing are closely related. That is, those cattle which will produce the most carcass weight of the desired grade at the youngest age will be the most efficient utilizers of feed. These desirable traits also appear to be closely related to appetite or feed intake.

In general, larger cattle will eat more feed per head daily and gain at a faster absolute rate. However, when appetite is expressed in terms of feed intake per unit of body weight, it is more closely related to feed efficiency, relative gain, and rate of maturing. Heifers consume more feed per unit of weight than steers (Tables 13 and 14) and bulls (15) and steers more than bulls (14). More early maturing breeds of cattle also consume more feed per unit of weight daily than later maturing types (Table 10).

When fed the same ration to a similar body composition, differences in feed efficiency among cattle of different types and sexes are relatively small, even though there are large differences in slaughter weight and age. These differences in age appear to be related to differences in feed intake per unit of weight, appetite, and this difference becomes of importance in considering interactions which exist among types of cattle and types of feed or feeding systems.

Data on interactions which may exist among types of cattle of the same sex and types of diet are somewhat limited. However, differences among bulls, steers, and heifers in rate of gain, feed intake per unit of weight, rate of maturing, and carcass weight and composition are very similar to differences which exist among different sizes of cattle. If this analogy between sex and size may be made and the two are considered together, there appear to be definite interactions among types of cattle and either types of diet or feeding systems. As reported in Section V, Angus steers attained a higher grade on an all-silage ration than Charolais steers. In Section VI, heifers made more efficient use of an all-silage ration than steers. In an earlier experiment, significant interactions between both breed (Hereford and Charolais) and sex (steers and heifers) and two systems of management were reported (12). The two systems of management were: creep-feeding and finishing immediately following weaning vs. no creep-feeding, wintering, grazing for 60 days, and finishing in dry lot. In combining the two sources of variation, breed and sex, it appeared that Charolais steers were best adapted to the early finishing system and Hereford heifers to the deferred system of management. It is well known that heifers finish more easily than steers and if bulls are to be finished at young ages they must be fed high energy rations.

It is therefore apparent that, if it is most economical to feed lower energy rations, they will be best utilized by early maturing types of cattle which consume more feed per unit of weight, and if high grain rations are to be fed, later maturing cattle will produce heavier, more desirable carcasses. If early maturing cattle are fed high grain rations at young ages, they must be slaughtered at light weights or they will become excessively fat.

As presented in Section III, the desirable traits of relative gain, feed intake per unit of weight, and rate of maturity may be combined in the single observation of 1/age at slaughter when carcass composition is constant. The importance of this trait in a selective breeding program needs further study to determine the percent of total variation which would respond to selection. The variation found in this trait was 7%, which is similar to the 5% variation in relative gain reported by Taylor (22) and considerably less than the 15% frequently observed in absolute gain. With the rather small variation in 1/age and relative gain, genetic progress through selection for either would likely be slower than selection for absolute gain. However, since these traits are much more closely related to feed efficiency, such selection should yield more progress in feed efficiency than has been realized from selection for absolute rate of gain.

The results reported here are in agreement with observations made by Reid (21). He reported that the variation in efficiency with which energy consumed above maintenance is utilized by cattle is about 6% and that individual animals appear to differ primarily in amount of feed consumed and in the level of feed intake at which they store appreciable amounts of fat.

With the small variations in maintenance requirements and efficiency of energy use above maintenance which exist among types of cattle, it appears that progress in feed efficiency of beef cattle will be slow. However, in view of its importance to the industry, every effort should be made to select cattle on those traits which will most likely improve efficiency. The greatest immediate improvement in efficiency of the total beef industry would be realized by matching types of cattle with those rations or feeding systems to which they are best adapted.

VIII. Summary and Conclusions

A series of experiments was conducted with mature cows, growing heifers, and growing and finishing steers and heifers to compare the energy requirements of cattle varying in size, breed, and sex and to determine if interactions exist among them and levels of energy in the rations fed.

Fat cows were found to have lower maintenance requirements per unit of weight than thin cows. If there are differences in maintenance needs among types of cattle, they appear to be small and related to differences in condition or in physiological age.

When cattle of different types are fed for similar periods of time or to similar weights, there are large differences among them in rate of gain, efficiency of gain, and carcass composition. If fed to similar carcass composition, differences in feed efficiency are small but differences in final weight and age at slaughter are large.

Since the results reported here indicate only small differences in maintenance requirements and in efficiency of energy storage above maintenance, it may be concluded that NRC energy requirements are applicable to cattle of different sizes and breeds.

The most significant differences among sizes and sexes of cattle is in age at slaughter (condition constant) or in rate of maturing. This difference was found to be directly related to appetite, with early maturing cattle consuming more feed per unit of body weight daily than later maturing types.

Differences among sexes of cattle in rate of gain, feed intake per unit of weight, rate of maturing, carcass weight, and composition are very similar to differences which exist among different sizes of cattle. Heifers consume more feed per unit of body weight daily and mature earlier than steers or bulls, and small types eat more per unit of weight and finish sooner than larger types.

If the two sources of variation, sex and size, are considered together, there appear to be definite interactions among types of cattle and rations or feeding systems. Lower energy rations or deferred systems will be best utilized by early maturing types which consume more feed per unit of weight, and if high grain rations are fed at young ages, later maturing types will produce heavier, more desirable carcasses.

Traits which seem of most importance for increasing feed efficiency in beef cattle are feed intake or gain per unit of body weight and the ability to finish at a desirable carcass weight. Those cattle which will produce the most carcass weight of the desired grade at the youngest age will be the most efficient. These traits may be combined in a single observation by expressing weight per day of age as a percentage of final weight when body composition is constant.

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